ISSN 2409-2665
Journal of Logistics, Informatics and Service Science
Vol. 9 (2022) No.4, pp.15-26
DOI:10.33168/LISS.2022.0402

Trend Analysis of Forest Fire in Pahang, Malaysia from 2001-2021 with Google Earth Engine Platform

Yee Jian Chew [1], Shih Yin Ooi [1], Ying Han Pang[1], Kok-Seng Wong [2]

[1] Faculty of Information Science and Technology, Multimedia University, Jalan Ayer Keroh Lama, Melaka, Malaysia

[2] College of Engineering and Computer Science, VinUniversity, Hanoi, Vietnam

syooi@mmu.edu.my

Abstract. Remote sensing imagery is one of the cost-efficient solutions to observe forest fire occurrence in a particular region. With the accessibility of more public remote sensing data, researchers and field experts can exploit the data to perform experimental analyses. In this paper, the entire state of Pahang in Malaysia has been selected to perform the fire activity trend analysis using the FIRMS hotspots public remote sensing dataset. The region is chosen because it has the largest forest reserve in Peninsular Malaysia and many fire incidences had been reported since 1998. The Google Earth Engine big data platform specifically the 20-years FIRMS hotspots dataset from 1st January 2001 to 31st December 2021 was used to observe the temporal and spatial trend of fire incidents in Pahang. The temporal analysis enacted reveals that the month from February to April every year is the occasional strong fire season. This scenario can be surmised by the hot and dry seasons encountered. On the other hand, the spatial analysis affirms the south-eastern part of Pahang state, the district of Pekan to be extremely susceptible to fire when compared to other districts. Additionally, this analysis also uncovered several high-risk fire regions that are positioned in the district of Jerantut, Temerloh, Kuala Rompin, Bentong, Bera, and Kuantan. Through these analyses, early preparations to tackle the forest fire can undoubtedly inhibit or decrease the seriousness of the tragedy. In future, other datasets such as rainfall, temperature, landcover, etc. can be used jointly with the FIRMS hotspots dataset to further investigate the prominent factors which are responsible for a fire incident in the state of Pahang.

Keywords: Forest Fire, Hotspots, Malaysia, Google Earth Engine, Temporal and Spatial Analysis

1. Introduction

Forest fire has been affecting a tremendous number of human lives, flora, and fauna every year across the globe. Many solutions (Alkhatib, 2014) from multiple perspectives had been devised to provide early detection and warning of forest fire before it spreads and becomes uncontrollable. Some of them include human observation through watchtowers (Alkhatib, 2014), digital cameras (Mathews et al., 2010), unmanned aerial vehicles (Yuan et al., 2015), and wireless sensors (Bahrepour et al., 2008). Although they are effective in preventing serious fire incidents, most of them required sufficient and usually large amounts of funds to deploy and maintain the infrastructure. Hence, this paper proposed a working framework that utilises the public satellite remote imagery to perform a trend analysis of the fire incidents due to its cost-effective mechanism.

In this paper, Google Earth Engine (GEE) big data platform is leveraged to outline the temporal and spatial patterns of the fire incident. We have selected the entire state of Pahang in Malaysia to perform the analysis. The 20 years of historical fire hotspots from the Fire Information for Resource Management System (FIRMS) dataset are exploited to determine the high-risk period and region in the state of Pahang.

2. Study Area

The study area selected in this study is the entire state of Pahang in Malaysia. Historically, Jamaruppin et al. (2016) reported that the district of Pekan in Pahang had been struck with fire incidents since 1998. In recent years, several newspaper articles had also reported the Pahang forest fire tragedy in the year of 2016 (Malaysia Kini, 2016), 2018 (Astro Awani, 2018; Bernama, 2018), 2019 (Alagesh, 2019), and 2021 (Awang, 2021). Figure 1 presents the area of interest in this work.

3. Related Works

With the study area fixated in the state of Pahang, all initiatives and efforts to battle the forest fire undertaken in the past will be disclosed in this section.

Setiawan et al. (2004) proposed a Spatially Weighted Index Model that considers several influencing fire factors including land cover, slope, aspect, elevation, and distance to road from the forest to generate a fire susceptibility map for the district of Pekan in Pahang located in the south-east of Pahang. The authors then compare the model with the fire hotspots in 1997, and they discovered that most of the fire occurrences recorded in 1997 were distributed across the high or very high-risk regions on the fire risk map. Thus, they postulated that the devised model was a suitable solution to effectively classify the fire risk of an area.

Mahmud et al. (2009) developed a user-friendly fire hazard mapping system in ArcView to simplify the process of delivering the fire susceptibility map. Some of the derived parameters such as elevation, aspect, slope, and distance to road were supplied as the fire factors into the analytical hierarchy process tools to weight the contribution of each factor. These weights were further evaluated by the experts from the Pahang State Forestry Department before utilising them in the production of a fire map for Pekan, Pahang. The primary goal of the proposed system was to enable users with little to no experience with Geographic Information System (GIS) to produce a fire susceptibility map.

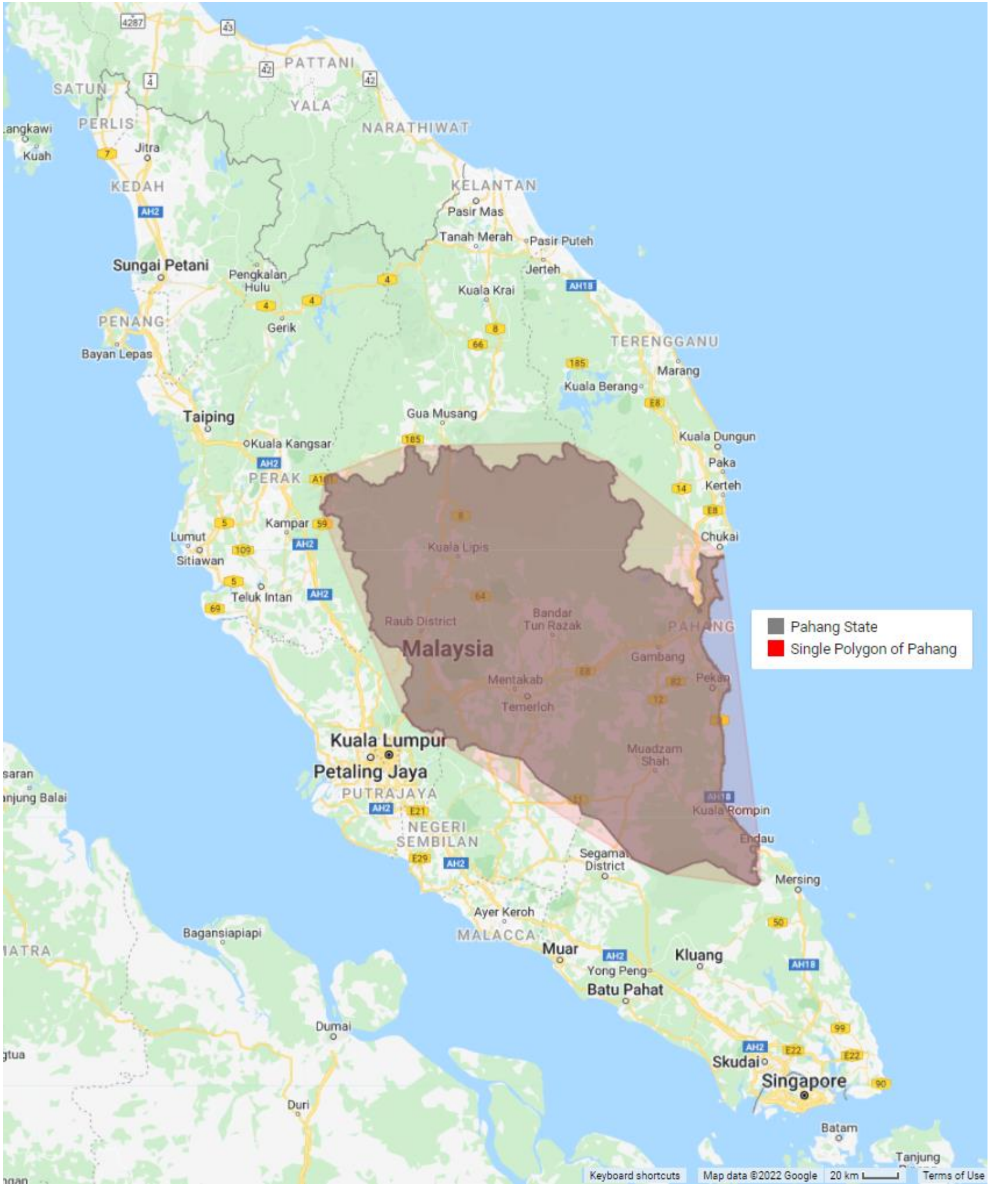

Fig. 1: The region of interest for hotspot distribution analysis

Razali et al. (2010) intend to investigate the fire factors for the severe forest fire that happened in 1998 in Jalan Pekan, Pahang. The authors consider the land cover, distance to road, and canal buffers to deliver the fire risk map using ArcGIS software. To validate the results, they also compare the fire risk map against the National Oceanic Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites (POES) hotspots.

Ismail et al. (2011) integrated multiple forest fire influencing factors such as bulk density, moisture content, dryness index, peat depth, etc., to generate the fire susceptibility map for several forest reserves in Peninsular Malaysia. Some of the forests include Pekan forest reserve, Nenasi forest reserve, Resak forest reserve, Kuala Langat forest reserve, etc. It should be highlighted that the methodology involved to amalgamate the factors and algorithms was not presented in the paper.

Jamaruppin et al. (2016) exploited the Land Surface Brightness Temperature from Landsat 8 thermal band 10 to discover the forest fire incidence that happened in March 2014 in Pekan, Pahang. The authors first recorded the temperature before the fire (28 January 2014), during the fire (1 March 2014), and after the fire (17 March 2014). By measuring the difference in the temperature before and during the fire, the author discover that the temperature of the region affected by the fire showed a significant increase. Hence, they can deduce and pinpoint the location of the fire occurrence by quantifying the difference in temperatures.

From the literature, it can be observed that none of the studies had performed a temporal and spatial analysis on the distribution of hotspots to uncover the trend of fire activity in the state of Pahang, Malaysia. Although Ash'aari and Badrunsham (2014) and Leewe et al. (2016) had conducted a temporal and spatial analysis in the past in Malaysia, Leewe et al. (2016) focused their work on the state of Sabah while Ash'aari and Badrunsham (2014) utilised Along Track Scanning Radiometer (ATSR) World Fire Atlas hotspot data. In this paper, we proposed to employ the FIRMS (*MODIS Collection 6 NRT Hotspot*, 2021) fire hotspots dataset by exploiting the GEE (Gorelick et al., 2017) big data platform to analyse the temporal and spatial trend of fire activity in Pahang, Malaysia.

4. Methodology

GEE is a cloud platform provided by Google to perform geospatial analysis at a planetary scale (Gorelick et al., 2017). With the tremendous computational resources provided by the platform, researchers can relieve a huge amount of computational power that is required to perform geospatial analysis locally using GIS tools such as ArcGIS, ArcView, or QGIS. Since the scripts on GEE can be easily shared with others, the solutions can be effortlessly replicated and performed in different regions (Gomes et al., 2020).

Though the temporal analysis of FIRMS hotspots through GEE had not been conducted in the state of Pahang, this sort of analysis had been adopted successfully in (Pratamasari et al., 2020; Sulova & Jokar Arsanjani, 2021) to understand the trend of the fire incidents. FIRMS (*MODIS Collection 6 NRT Hotspot*, 2021) dataset from GEE represents any active fire pixels at 1 km^2 spatial resolution.

In general, the active fire hotspots include any active fire activity and thermal anomalies (e.g., volcanoes) (Giglio, 2018). In this paper, 20 years of FIRMS hotspots data from 1st January 2001 to 31st December 2021 are utilised to perform the analysis. Figure 2 presents the overall methodology proposed. It should be noted that the single large polygon for the region of interest is employed to reduce the computational resources required for the ui.Chart.image GEE function. Instead of using the 1 km^2 spatial resolution, the native resolution of the dataset (~926 m^2) is employed to achieve more competent analysis results.

For result replication, we also disclosed our source code in Github: *https://github.com/chewyeejian/GEE_Hotspot_Pahang.*

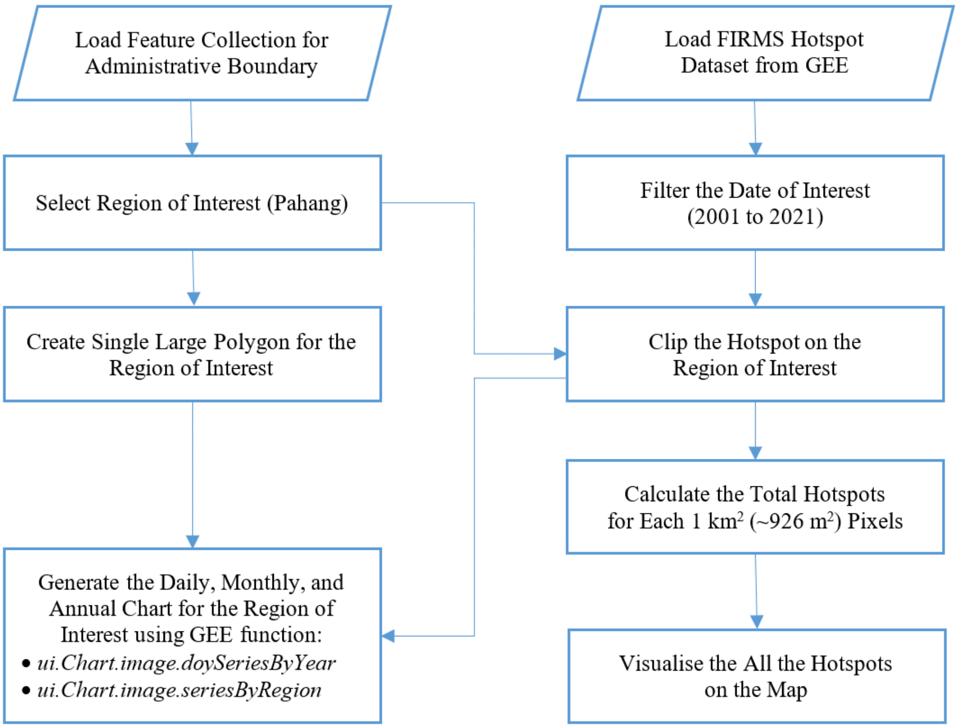

Fig. 2: Overall methodology of the proposed work

5. Results and Analysis

5.1. Temporal Analysis

To reveal the temporal trend of forest fire occurrence in the state of Pahang, Figure 3 – Figure 6 are generated to perform the task. All the figures and graphs deliberated in this paper are created by using GEE Code Editor (Javascript). Although the results from the graphs can be exported to a CSV format to build and design charts that can provide more insights, we intentionally retain the default graphs from GEE to allow other researchers to replicate the procedure.

Figure 3 depicts the total number of fire hotspots in 1 km^2 (926 m^2) per pixel for each year from 2001 to 2021. The highest number of fire hotspots detected was in the years 2005 (7,564 hotspots), 2014 (9,327 hotspots), and 2019 (7,278 hotspots). Over the last 20 years, more than 2000 hotspots were regularly noticed every year, except in the years 2007 and 2017.

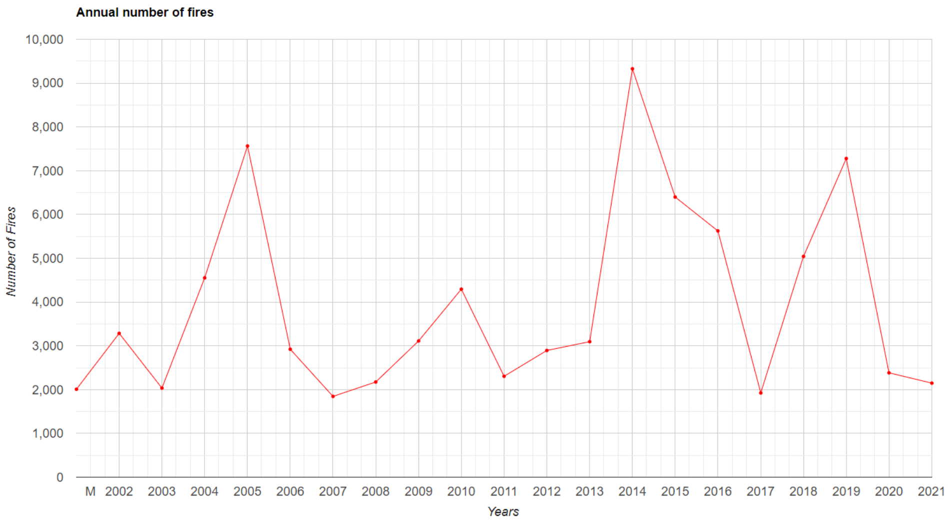

Fig. 3: Total number of hotspots detected annually from 1st January 2001 to 31st December 2021

To ascertain the months with the most fire incidents, Figure 4 presents the total number of monthly hotspots across 20 years in chronological order. From the analysis, an obvious trend pattern is discovered and showing that the peak of each year is exhibited from February to April. This can be speculated by the hot and dry period experienced in these months (Gasim et al., 2006). It should be noted that the charts produced are interactive, whereby users can view the respective number of hotspots and months by hovering over each of the red dots. To extend the hypothesis made from Figure 4, Figure 5 is plotted based on the number of monthly hotspots across the year. Figure 5 evidently exposed that February, March, and April comprise the highest number of fire incidents. These findings further support the claims accentuated in Jamaruppin et al. (2016), whereby forest fire incidents were mainly spotted from February to April.

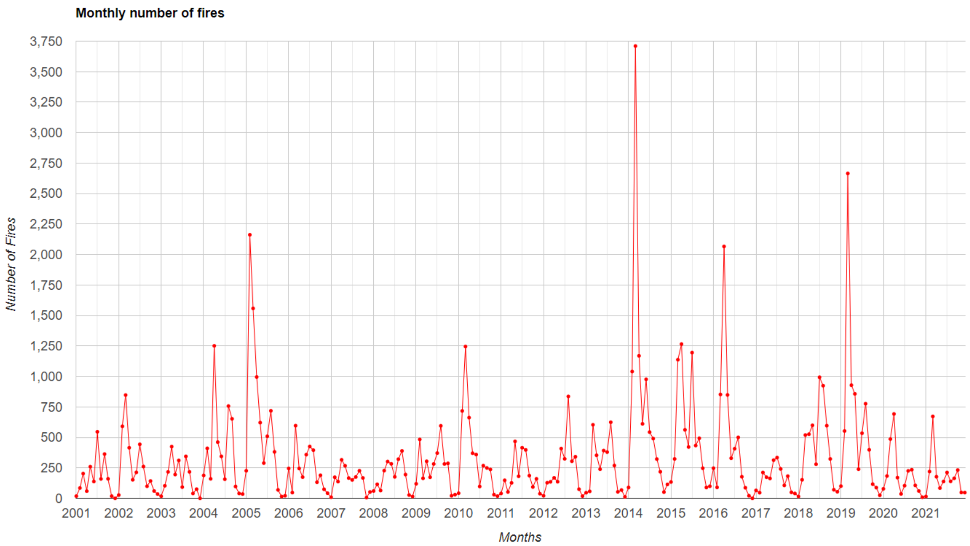

Fig. 4: Total number of hotspots detected monthly arranged in chronological order from 1st January 2001 to 31st December 2021

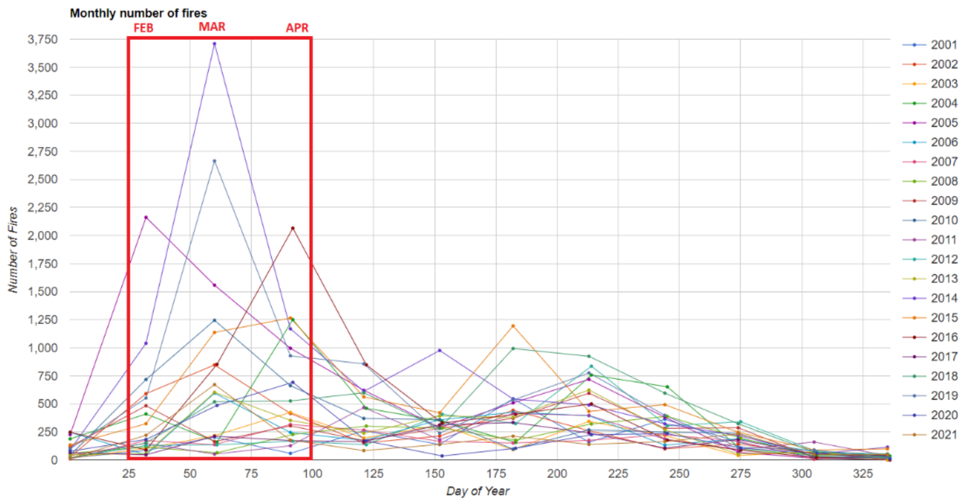

Fig. 5: Total number of hotspots detected monthly arranged annually from 1st January 2001 to 31st December 2021

Figure 6 shows the number of daily hotspots across the period of a year from 2010 to 2021. Akin to the observation from the earlier figures, the number of hotspots substantially concentrated around Day 50 (February) to Day 120 (April) of the year.

For the number of daily hotspots presented in Figure 6, only the dataset from 2010 to 2021 is utilised in this analysis due to the limitation of GEE, as the platform cannot process more than 5000 elements to generate the chart.

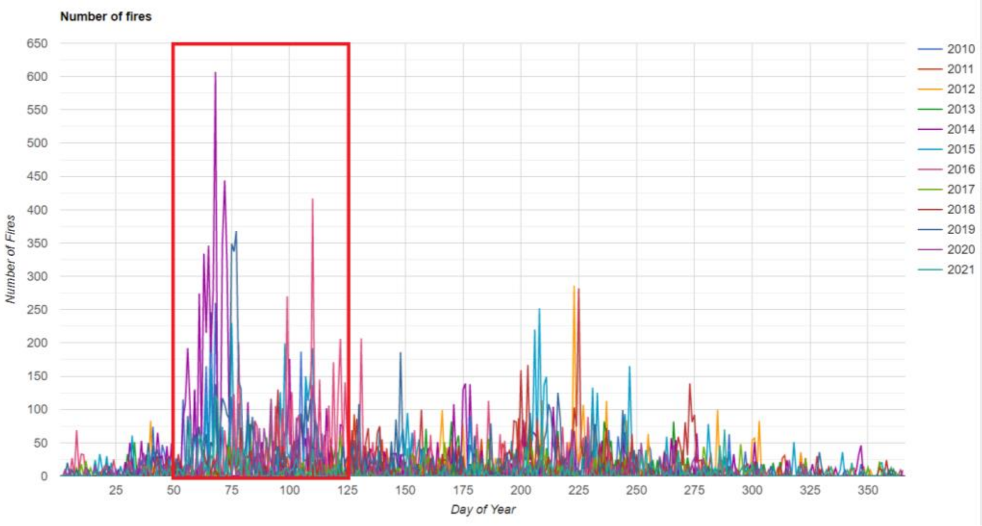

Fig. 6: Total number of hotspots detected daily from 1st January 2010 to 31st December 2021

5.2. Spatial Analysis

A simple spatial analysis exploiting the 20 years of historical hotspots from FIRMS is used to identify the high-risk regions in the state of Pahang. The spatial distribution of the total cumulative number of hotspots per 1 km2 (926 m2) from 2001 to 2021 is reflected in Figure 7. We noticed that a remarkable number of hotspots are intensely focusing on the south-eastern part of Pahang. This result is very encouraging, as most of the historical forest fire incidents reported by the news (Alagesh, 2019; Astro Awani, 2018; Awang, 2021; Bernama, 2018; Malaysia Kini, 2016) and literature (Ismail et al., 2011; Jamaruppin et al., 2016; Mahmud et al., 2009; Razali et al., 2010; Setiawan et al., 2004) were materialised in the district of Pekan located in the south-eastern of Pahang state. Apart from the district of Pekan, Jerantut (~231 hotspots), Termerloh (~159 hotspots), Kuala Rompin (~91 hotspots), Bentong (~81 hotspots), Bera (~79 hotspots), and Kuantan (~59 or 65 hotspots) also reveal approximate or more than 100 hotspots over the past 20 years. Thus, it was worth undertaking further investigation on these locations in the future to understand the factors of the fire occurrences.

6. Conclusion

The temporal and spatial patterns of the fire incidents in the state of Pahang are scrutinised in this paper by utilising the GEE platforms with the FIRMS hotspots dataset. To conclude, February to April were the months distinguished with the highest number of fire incidents in the state of Pahang based on the 20 years of historical fire hotspots from the FIRMS dataset. This is conditionally true because Malaysia is encountering hot and dry weather from February to April (Gasim et al., 2006) which subsequently results in the reduction of moisture in the soil. Additionally, the straightforward spatial analysis echoes the claims made by previous studies (Ismail et al., 2011; Jamaruppin et al., 2016; Mahmud et al., 2009; Razali et al., 2010; Setiawan et al., 2004), which assert the district of Pekan located in the south-eastern of Pahang to be a highly vulnerable fire-prone region. By recognising the soaring fire periods and locations, firefighting resources can be allocated efficiently to combat the fire to prevent or reduce the severity of each fire incidence.

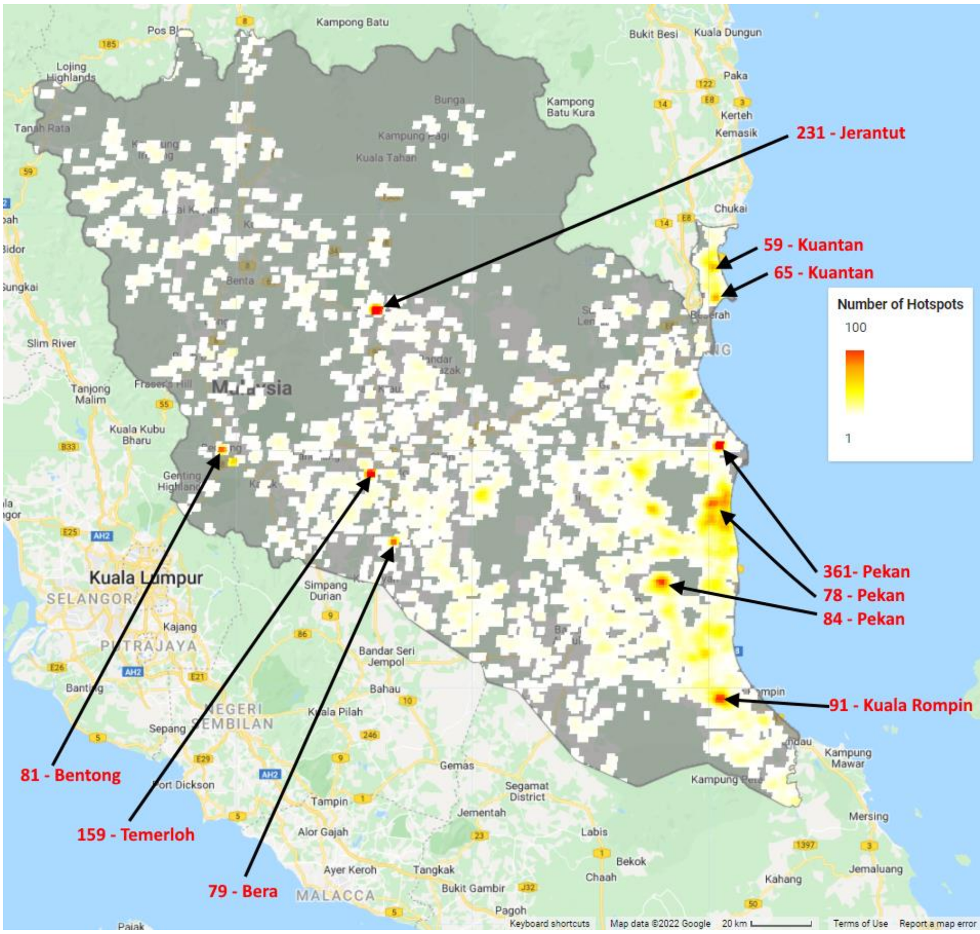

Fig. 7: Total number of hotspots detected for each 1 km2 (926 m2) from 1st January 2001 to 31st December 2021

In future, meteorological data (e.g., temperature), environmental data (e.g., land cover), topography data (e.g., elevation), and social-economic data (e.g., human population) can be integrated with the hotspots data to discover the correlation between each of the factors and the fire incidences. Meanwhile, the identical analysis procedure demonstrated in this paper can be reperformed over the entire Peninsular Malaysia, the state of Sabah and Sarawak, or the entire globe.

Acknowledgements

This research work was supported by a Fundamental Research Grant Schemes (FRGS) under the Ministry of Education and Multimedia University, Malaysia (Project ID: FRGS/1/2020/ICT02/MMU/02/2), and Korea Foundation of Advanced Studies (ISEF).

References

Alagesh, T. N. (2019, February 26). 40ha of Pahang forest, peat land on fire. New Straits Times. https://www.nst.com.my/news/nation/2019/02/463995/40ha-pahang-forest-peat-land-fire-nsttv

Alkhatib, A. A. A. (2014). A review on forest fire detection techniques. International Journal of Distributed Sensor Networks, 2014(3), 597368. https://doi.org/10.1155/2014/597368

Ash'aari, Z. H., & Badrunsham, A. S. (2014). Spatial Temporal Analysis of Forest Fire in Malaysia Using ATSR Satellite Measurement. Bulletin of Environmental Science and Sustainable Management, 2(1).

Astro Awani. (2018, September 30). Kebakaran hutan simpan Pekan tak membimbangkan (Fire in Pekan Forest Reserve is not a concern). https://www.astroawani.com/berita-malaysia/kebakaran-hutan-simpan-pekan-tak-membimbangkan-186979

Awang, A. (2021). Lebih 300 hektar hutan di Pahang terbakar (More than 300 hectare of forest burnt in Pahang). Berita Harian. https://www.bharian.com.my/berita/wilayah/2021/03/795145/lebih-300-hektar-hutan-di-pahang-terbakar

Bahrepour, M., Meratnia, N., & Havinga, P. J. M. (2008). Automatic fire detection: A survey from wireless sensor network perspective. Pervasive System Group, Univeristy of Twente.

Bernama. (2018, October 1). Kebakaran Hutan Simpan Pekan: Anggota bomba, Jabatan Perhutanan terkandas (Fire in Pekan Forest Reserve: Fire fighters, Forestry Department is stranded). https://www.utusanborneo.com.my/2018/10/01/kebakaran-hutan-simpan-pekan-anggota-bomba-jabatan-perhutanan-terkandas

Gasim, M. B., Toriman, M. E., Rahim, S. A., Islam, M. S., Tan, C. C., & Juahir, H. (2006). Hydrology and water quality and land-use assessment of Tasik Chini's feeder rivers, Pahang Malaysia. Geografia, 3(3), 1–16.

Giglio, L. (2018). MODIS Collection 4 Active Fire Product User ' s Guide Table of Contents. Revisión B. Nasa, 1(June), 64. https://modis-fire.umd.edu/files/MODIS_C6_Fire_User_Guide_B.pdf

Gomes, V. C. F., Queiroz, G. R., & Ferreira, K. R. (2020). An overview of platforms for big earth observation data management and analysis. Remote Sensing, 12(8), 1253.

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment, 202, 18–27.

Ismail, P., Shamsudin, I., & Khali Aziz, H. (2011). Development of indicators for assessing susceptibility of degraded peatland areas to forest fires in Peninsular Malaysia. IUFRO World Series Volume 29, 67.

Jamaruppin, M. E. Bin, Bayuaji, L., Ab Ghani, N. B., Rahman, M. A., Akashah, F. W., & Shah, A. (2016). Forest fire occurrence analysis base on land brightness temperature using Landsat data (Study area: Jalan Kuantan–Pekan, Pahang, Malaysia). The National Conference for Postgraduate Research.

Leewe, Y., Ahmad, A. N., Ismail, A., & Sheriza, M. R. (2016). Analysis of hotspot pattern distribution at Sabah, Malaysia for forest fire management. Journal of Environmental Science and Technology, 9(3), 291–295.

Mahmud, A., Setiawan, I., Mansor, S., Shariff, A., Pradhan, B., & Nuruddin, A. (2009). Utilization of geoinformation tools for the development of forest fire hazard mapping system: example of Pekan fire, Malaysia. Open Geosciences, 1(4), 456–462.

Malaysia Kini. (2016, April 29). Hutan seluas 34 hektar terbakar di Kuantan (A 34-hectare forest burned in Kuantan). https://www.malaysiakini.com/news/339616

Mathews, S., Sullivan, A., Gould, J., Hurley, R., Ellis, P., & Larmour, J. (2010). Evaluation of three fire detection systems. Australia: Bushfire Cooperative Research Centre.

MODIS Collection 6 NRT Hotspot. (2021). https://doi.org/10.5067/FIRMS/MODIS/MCD14DL.NRT.006

Pratamasari, A., Permatasari, N. K. F., Pramudiyasari, T., Manessa, M. D. M., & Supriatna, S. (2020). Spatial distribution patterns analysis of hotspot in Central Kalimantan using fimrs modis data. Journal of Geography of Tropical Environments, 4(1).

Razali, S. M., Nuruddin, A. A., Malek, I. A., & Patah, N. A. (2010). Forest fire hazard rating assessment in peat swamp forest using Landsat thematic mapper image. Journal of Applied Remote Sensing, 4(1), 43531.

Setiawan, I., Mahmud, A. R., Mansor, S., Shariff, A. R. M., & Nuruddin, A. A. (2004). GIS - grid - based and multi - criteria analysis for identifying and mapping peat swamp forest fire hazard in Pahang, Malaysia. Disaster Prevention and Management: An International Journal.

Sulova, A., & Jokar Arsanjani, J. (2021). Exploratory analysis of driving force of wildfires in Australia: An application of machine learning within Google Earth engine. Remote Sensing, 13(1), 10.

Yuan, C., Zhang, Y., & Liu, Z. (2015). A survey on technologies for automatic forest fire monitoring, detection, and fighting using unmanned aerial vehicles and remote sensing techniques. Canadian Journal of Forest Research, 45(7), 783–792.